The Effects of a Nuclear Power Plant on Property Values - The Swedish Case of Forsmark

Karin Ewelönn*

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Abstract

This study analyses the impact of a nuclear power plant on residential property values in Sweden during the period 2005-2009. A nuclear power plant could theoretically influence the price of a house in a number of ways. Compensation for possible hazard might become apparent through higher transaction prices with distance to the plant and a reasonable contradiction would be the effect of workers appreciating the vicinity to their job site. Assessing monetary value to environmental goods and services is difficult as they cannot be found on the market. To analyze potential risk of living in proximity to a nuclear power plant an assumption of marketed goods implicitly carrying the value of an unmarked good must be made. By observing transaction prices for houses adjacent to a plant, the value of public perceived risk can be extracted from the purchase through hedonic estimation. The main findings presents no significant decrease in prices with distance to the nuclear power plant Forsmark and consequently does not support the argument of a negative effect on close surroundings. As the positive distance estimate is very close to significant it cannot be excluded that a larger number of observations could change the significance of the results.

Keywords: Hedonic house price model, nuclear power plant

JEL-classification:
Acknowledgements

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1 Introduction

Despite running on scares resources with a production subject to risk, the nuclear power is yet to be replaced. Its advantage of generating a high amount of electrical energy with low emissions of green house gases makes it difficult to find an equivalent substitute of risk-free and environmentally sound nature. The present nuclear power plants in Sweden needs to be replaced within fifteen years and creating a new energy producing power plant takes at least ten years (Kloow 2011). As the new nuclear power law in Sweden demand unlimited responsibility taken by power companies constructing the plants, a stagnant decision process might follow and thus contributing to the remaining of old plants with higher concern for maintenance. The prevalence of the nuclear power gives matter to analyzing the externality of risk, i.e. the awareness of potential hazard becoming present when living close to a power plant.

This study evaluates a nuclear power plants effect on property values with the purpose of measuring the impact of the plausible risk of living in vicinity to such a facility. A hedonic house price model is applied together with a GIS to find that prices on properties do not significantly increase with distance.

The Swedish nuclear power plant Forsmark is located on the east coast in Östhammar municipality. It has been active since 1980 and is mainly owned by the Swedish government. In recent years the plant received attention after experiencing difficulties with their power supply. There still lies a discussion of wether a meltdown could have been possible from the complications that arose and the event is classified as a level two incident on INES\textsuperscript{1}. During maintenance service in July 2006 a short circuit arose in Forsmark. This caused large parts of measuring, registering and monitoring capabilities in the control room to disappear. The electric engines to the cooling pumps did not get voltage and as a consequence the water level in the reactor tank decreased, heating the nuclear fuel. After 22 minutes the staff connected the General Electricity and the pumps were rebooted. The incident appeared due to the under frequency protection which was not correctly connected and could not function as intended (Forsmarks Kraftgrupp, 2006). The probability of a meltdown were at first rejected by the management of Forsmark. Later a representative from the Swedish Radiation Protection Institute confirmed that a meltdown technically could have been possible and calculations made by Forsmarks’

\textsuperscript{1}The International Nuclear and Radiological Event Scale, used to communicate the meaning of security in nuclear and radiation related events to the public and media. The scale constitutes how serious an event is through three aspects: Human and environment, function of the barriers that are to prevent radioactive emission and defense in depth. 1-3 are classified as incidents and 4-7 are classified as accidents (SSM 2011b).
own technicians showed that the probability was 1/52 of a meltdown due to the complications that emerged (Sveriges Radio P3 2011).

Elaborating forecasts, on the other hand, in the area of nuclear power is problematic. The many variables affecting a nuclear power plant makes according to Karlsson (2011) calculating probabilities of a meltdown complicated. Every power plant is different and every country has different affective factors, even the Swedish nuclear power plants differ amongst themselves. Probability calculations made by the Swedish Radiation Safety Authority (SSM) are thus not intended to anticipate nuclear accidents. Their task is rather to identify weaknesses in the construction and subsequently make improvements.

In the light of other more serious nuclear accidents such as Chernobyl, Three Mile Island and most recently Fukushima an assumption of associated risk with living in vicinity to a nuclear power plant is not very far fetched. The value of the risk could be assigned by prices on residential properties and nuclear power plants might thus become an externality, should it lower surrounding property values as a compensation for the possible hazard. Earlier studies on environmental goods often express the assumption that positive and negative externalities could have an effect on property values.

For policy makers to implement environmental principles knowledge is required about the supply and demand for environmental goods, such as the willingness to pay for them. Here a problem arises; as environmental goods are not traded on the market no price can be observed. Throughout the literature on the subject this problem is most commonly solved through hedonic estimation. The model estimates the value of environmental quality and amenities as they affect the price of a marketed good. Hedonic house price models are based on the assumption that residential properties are related to a bundle of attributes specific for the house along with neighborhood characteristics, which people consider important when making their purchase.

The results from previous studies estimating the effect of nuclear power plants on property values are mixed, though with a small advantage for negative results. Estimates on contamination sites where accidents have occurred demonstrate a negative impact on property values (Simons 1999, Carroll et al 1996, Gamble and Downing 1982). Studies on nuclear power plant areas with no accident show mixed results. Gamble and Downing (1982), Clark et al (1997), Clark and Metz (1997) show a negative relationship, however not significant, and Simons and Saginor (2006) and Boyle and Kiel (2001) find significant negative results. Papers on other negative externalities which are not connected to accidents, such as Winstrand (2009) and Blomquist (1974), show significant negative results on residential properties.

\[\text{See for instance Simons and Saginor (2009), Boyle and Kiel (2001) and Jackson (2001).}\]
This paper estimates the influence of the Swedish nuclear power plant Forsmark on adjacent house prices with the purpose of measuring the economic value of the asserted risk of living in proximity to a nuclear power plant. The method of choice is a hedonic house price model accompanied by a Geographic Information System (GIS), where geocoded coordinates retrieve the distance between each property and Forsmark. The data set was created with statistics from Mäklarstatistik for the five-year period 2005-2009 which thus covers the incident in 2006. It includes transaction prices and structural characteristics on single-family houses sold in Östhammar municipality, coordinates, an ocean dummy and year dummies. The main findings include no significant negative effect on prices of residential properties in vicinity to the power plant. The positive distance estimate is however very close to a significance of 10 percent. The contribution of an ocean dummy caused distance to change from negative to positive, proposing that additional observations and characteristics possibly could result in a larger and significant distance coefficient.

A review of previous studies on environmental externalities will follow this section. The third section constitutes the theoretical framework with an analysis of externalities. Section four describes the empirical framework and the results are presented in section five. Concluding remarks are compiled in section six.

2 Previous studies

Hedonic pricing models have been used extensively to estimate the effect of environmental externalities on property values. The very foundation of the model has been developed by several economists and amongst the most mentioned contributions are Lancaster (1966), Ridker and Henning (1967), Rosen (1974), Blomquist (1974) and Freeman (1979). Hedonic methods appear to be common in studies estimating nuclear power plants impact on property values. A primary paper on the subject is Gamble and Downing (1982). The authors first analyze the effect of four American nuclear power plants before the Three Mile Island (TMI) Harrisburg accident. Secondly, they estimate the effect of the accident in vicinity to TMI. The first case shows neither positive nor negative significant effects on property values in proximity to the plants. In the second case the number of sales appearing close to the TMI plant dropped considerably after the accident and distance from plant was statistically significant prior to the accident but not after. It is suggested that this might be due to increased clean-up personnel and nuclear technicians, which increased employment after the accident.
Two nuclear power plants that have been subject to a number of studies are Rancho Seco and Diable Canyon in California. Clark et al (1997) examines the risk associated with living in proximity to these nuclear reactors and storage of nuclear waste. They find no significant support for residential house prices being affected by the plants. At one plant however, house prices raises with proximity to the plant. Clark and Metz (1997) estimated possible impacts from a decision to move spent nuclear fuel from wet storage to dry-cask storage facilities. Through surveys they find that the public have a negative viewpoint on anything nuclear and radioactive. However, decisions and announcements about spent nuclear fuel storage activities do not affect the residential property market. They find no effect on residential property prices regardless of if the plant is operating, closed or high-level radioactive waste is to be placed in dry-cask storage. Clark and Allison (1999) investigate how public knowledge of spent fuel storage at the plants affect the price of residential properties. The results show that proximity and visual reminders of a plant have some influence on local house prices.

Boyle and Kiel (2001) study the consistency of willingness to pay for environmental goods by reviewing several articles, all which have used hedonic house price models. The category that includes nuclear power plants is usually of the correct sign and statistically significant, however with quite large variation estimates. The authors argue that in cases where estimated results are not negative, it might be due to residents expectations of financial aid from the government. Simons and Saginor (2006) cover a number of articles on environmental contaminations effects by putting each empirical study's loss into a data set. Nuclear power plants has a quite large negative significant effect. When adding positive amenities however, it turned out positive and significant.

Some papers have shown a negative effect from other externalities. Winstrand (2009) explores the impact of non-aesthetic view and odour steaming from the Swedish refinery Preemraff on property values. The estimates show a small significant increase in house price with distance from the refinery. He also finds a small negative effect of the odour and strong negative effect of the view. Blomquist (1974) estimate the influence on property values from an electric utility power plant and illustrate damage on residential property value that decrease with distance to the power plant.

There are studies reflecting a negative effects on property values by environmental contaminations caused by accidents. For example Carroll et al (1996) analyzes the PEP-CON explosion. The estimates in one of their samples show that housing prices increase with distance; an effect that expanded after the explosion. Also, an announcement that

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3The Pacific Engineering Production Company of Nevada (PEPCON) experienced in 1988 a chemical fire and subsequent explosions affecting an area up to 16 kilometers.
the plant would be relocated made property values recoiled. Simons (1999) studied the
effect on single-family house and townhouse sales after a petroleum pipeline rupture in
Virginia in 1993. He found a reduction in sales prices for property on the pipeline, fol-
lowing 2 miles north of the rupture. There were no significant effects along the pipeline.
For the townhouses however, there were a reduction in sales price on the pipeline after
the rupture.

In more recent papers such as Clark and Allison (1999), Winstrand (2009) and Pa-
terson and Boyle (2002) the system GIS\textsuperscript{4} is applied. This is to create more specific
coordinates when measuring the distance between properties and externalities. The sys-
tem has shown some clear advantages when performing hedonic house price studies and
has lately become more current due to its topological features. This being of importance
when estimating the visible effect of an externality.

The aggregated result of the literature reviewed measuring willingness to pay for
environmental externalities, suggest a negative affect on property values.

3 \textbf{Theoretical Framework}

3.1 Externalities

The environment provides the economy with numerous services; resources used as input
to production, assimilation of by-products from production, amenity values, life support
etc. Nonetheless, assessing a monetary value to environmental goods and services can
be seen as problematic, policy makers are uneager to appraise a price on human life in
environmental policy. Adding a value to these goods and services can however enable
environmental impacts to be included in cost and benefit analysis. These analyses are
complex since environmental goods and services usually are under-priced or simply with-
out a price tag, often making them come of as free or as a public good, which in turn
gives them little influence in policymaking. This brings cause to a monetary valuation
of the environment (Cropper and Oats 1992, King and Mazzotta 2000).

To develop environmental policy one needs knowledge about the supply and demand
for environmental goods. This means obtaining peoples willingness to pay for environ-
mental quality. The price of a marketed good is fairly easy to observe through its demand
and supply curves, detecting the value of an environmental good however presents an
obstacle as they cannot be found on the market. Another technique must therefore be

\textsuperscript{4}For further reading: Bateman et. al (2002) and Lake et al (2000a) (200b).
developed to obtain the value of air and water quality, aesthetic views, distance from contamination sites etc. One such method is observing the price of a marketed good and thus in extension the value of the environment. When a consumer is purchasing a marketed good it is presumed that they are also implicitly buying an unmarked good, such as environmental goods. This technique is entitled hedonic estimation. When purchasing for example a residential property the buyer also receives the neighborhood and environmental characteristics. If these characteristics of the purchased good are regressed on its price, adding the environmental characteristics to the equation, the price of the environmental good could be extracted. (Boyle and Kiel 2001).

In addition to reasons such as aesthetics and/or odour affecting peoples choice of property, it is feasible that a certain risk is associated with living close to a toxic area. Radiation, toxic air and water could make you ill or even be fatal. From this one can make the assumption of a possible negative relationship between environmental contamination and the willingness to pay for houses in vicinity to such areas due to its risks. The distance to adjacent amenities or contamination sites could affect the market price of a residential property.

The literature on environmental economics shows that negative externalities, such as environmental contamination sites, in some cases cause house prices to increase with distance to the site. Consequently there is a possibility that negative externalities become a cost to society. Economic principles for environmental policy thus stems from the theory of externalities (Cropper and Oats 1992).

As it is plausible for an area associated with risk to affect the value of its surroundings this paper intends to estimate the possible impact of a nuclear power plant on residential property prices. Living in proximation to a nuclear power plant may include a risk of becoming exposed to radiation in the events of a leakage, this possible hazard can affect the prices of properties in such areas. The nuclear power plant Forsmark located on the east coast of Sweden will thus together with adjacent house prices be analyzed. The null-hypothesis consisting of the nuclear power plant having no effect on houses in its vicinity stands in contrast to the alternative hypothesis of an effect in either positive or negative direction.
4 Empirical Framework

4.1 The Hedonic house price model

When studying the effect of environmental quality and amenities hedonic house pricing is frequently the model of choice. Costs or benefits of externalities can theoretically be revealed by the variation in price of a residential property as they affect the market value. This is embedded in the assumption that each house has its own individual set of characteristics and that these all have an implicit price. The general form of the hedonic model is

\[ \text{Price} = f (\text{Physical Characteristics, Other Factors}) \]

The price of a house contains the value of all these characteristics, attributes that are marketed goods as well as un-marketed. It is thus feasible to estimate the implicit prices for un-marketed goods by controlling for the marketed goods and observing the remaining difference in price. The regression estimates will illustrate every variables implicit price. The transaction cost of house \( i \) \((i = 1 \ldots n)\) is a function of its individual characteristics \( Z_i \), \( \alpha \) being the implicit unknown price of the environmental quality. \( \epsilon \) is an error term.

\[ P = \alpha_1 Z_1 + \ldots + \alpha_n Z_n + \epsilon \]  \hspace{1cm} (1)

The assumption of a non-linear price function can be made as the cost of changing a set of house characteristics is very expensive once the house is built (Clark and Allison, 1999). According to Sirmans et al (2005) semi-logarithmic models are usually applied when estimating hedonic house price equations. The semi-log model will be

\[ P = e^{\alpha_1 Z_1 + \ldots + \alpha_n Z_n + \epsilon} \] \hspace{1cm} (2)

which can be rewritten as

\[ p = \ln P = \alpha_1 Z_1 + \ldots + \alpha_n Z_n + \epsilon \] \hspace{1cm} (3)

The dependent variable price is in natural logs whereas the independent variables are
unlogged. This is convenient as the value of each characteristic can vary and an easy interpretation of estimated parameters can be made. The percentage change in price for one-unit change in a variable can be calculated through the coefficient estimates. (Sirmans et al. 2005).

As it is plausible that Forsmark has an effect on the prices of housed in its vicinity, Euclidean distance denoted \(D_i\) is added to the equation

\[
p = \alpha_1 Z_1 + \beta_1 D_1 + ... + \alpha_n Z_n + \beta_n D_n + \epsilon
\]  

(4)

The use of distance with this type of arrangement does amount the assumption of equal effect in every direction. Directional effects could easily be heterogeneous due to prevailing winds and topography (Winstrand 2010). However, in the events of a larger nuclear accident this is reasonably not essential.

Approximation of the distribution of radioactive material from a nuclear accident into the air with the wind is made through range models. The distance of radioactive spread depends on how much is released, how far up in the air the material reaches, rain and the direction and strength of the wind. An explosion with large heat development would likely give a great spread. The area of concern is then calculated with great margin of safety, an example is SSMs recommended safety margin from Fukushima Dai-ichi which is 80 kilometers. Within that area people are in risk of exceeding the level of radiation dosage acceptable for people working with radiation, that is if the emission is large enough and you are located in the direction of the wind. It is thus plausible to assume risk of an effect on the environment within 40 kilometers range of a nuclear power plant if there were greater radioactive emissions (SSM 2011a and 2011c).

To get unbiased and efficient estimates using OLS it is required that the residuals are met by the \(iid\) criteria, i.e. the random variables are independent and identically distributed. However, in the presence of heteroskedasticity the OLS estimators are unbiased, implying that the standard test are unreliable. This has been found to be a problem with hedonic house price models, it is likely that at least some variables possibly provide the error term with heteroskedasticity since the hedonic house price model is quite general and could consist of many diverse variables.

Plausibly contributing to heteroskedasticity is the age variable, as an old property most likely has been improved at some point and a variable such as renovation could be hard to specify and assemble for a dataset (Goodman and Thibodeau, 1995). Further it is argued by Fletcher et al (2000) that very high age could make a house seem vintage,
which might increase the price, as it cannot be assumed that the relation between the house price and its age is neither linear nor monotonic. Thus justifying the amendment of age squared, an indication of vintage effects.

An adversity for the hedonic house price model is the spatial dependency. As the location of the house influences the property prices and the neighborhood characteristics will affect all the house prices, not just the one house, a risk of the residuals being spatially correlated develop. Should the characteristics be omitted or measured with error there will be spatial correlation and the residuals are no longer classified as iid (Winstrand 2010). One suggestion to avoid this is to use a spatial model. The most common sources of spatial correlation are omitted variables and measurement errors. To avoid the possible bias from excluded variables attributes other than the nuclear power plant itself that vary spatially could be included, such as rail roads, waste sites etc. (Clark and Allison 1999) Even if these were to be included there is still a possibility of getting biased results since variables can be spatially correlated with factors that are not measurable, such as the ”word of mouth”. The use of submarkets is another option of how to amend estimations subject to spatial dependency. It does however according to Winstrand (2010) seldom solve the problem.

A large set of structural attributes is favorable to reduce the risk of multicollinearity among structural characteristics (Winstrand 2010). This preferably large dataset containing many structural characteristic is also one of the shortcomings of the model. The data could be cumbersome to compile and is sometimes unified with a charge. With a spatial model it is most helpful to apply a GIS, this could however be time consuming if you do not have someone to guide you through its many techniques.

As Östhammar municipality is situated along the Swedish coastline it partially consist of an archipelago and thus some of the properties are adjacent to the ocean. Proximity to the ocean could be seen as a positive amenity and hence affect the transaction price (Simons and Saginor 2009). Consequently an ocean dummy is added to the model.

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5 Most commonly used in this context are the spatial autoregressive model (SAR) or the spatial error model (SEM). An exogenously determined spatial weight matrix is applied in both models to account for the spatial dependency. The degree of possible spatial dependency is determined by the weight matrix. For further reading: Wilhelmsson (2002), Pace and Gilley (1997).
4.2 Data

The data set for this study extends over the period 2005-2009, with the purpose of covering the incident at Forsmark in 2006. If the event had any effect on property values it should have been during this period. Usage of a five-year period is motivated through other studies such as Clark et al. (1997), Clark and Allison (1999) and Winstrand (2009). The transaction prices and structural characteristics of single family houses sold in Östhammar municipality, located south of Forsmark, are provided by Svensk Mäklarstatistik AB and the number of observations are 544. Structural characteristics include living area, rooms, the age of the property, age squared and the lot size.

An ocean dummy separates property areas in conjunction to the ocean, such as harbor settlements and islands, from the inland areas. The selection was based on the property designation in relation to maps and coordinates\(^6\). No precise distance was able to be produced.

The variable Euclidian distance from each property to the nuclear power plant is calculated with the help of a GIS. All property sales during the investigated period and the nuclear power plant Forsmark are geocoded with the two-dimensional coordinates RT90\(^7\). The coordinates of the houses are supplied by Mäklarstatistik AB and Forsmark was found manually. The precision error per coordinate is 100 meters, as this could be seen as not very precise one should keep in mind that Forsmark is in itself two kilometers squared and hence correcting the error would not change the results notably. The distance span contain properties up to approximately 40 kilometers from the plant.

Table 1 display descriptive statistics and the correlation coefficients for dependent and explanatory variables are presented in Table 2. All correlation coefficients are significant with price. Price and distance to Forsmark show a negative correlation indicating that price decrease with distance from the plant. Age and price are also negatively correlated which implies higher prices for houses of lower age. Living area, rooms, lot size and ocean all increase with price. The year dummy coefficients for 2005-2006 and price were negative whereas 2007-2009 showed a positive correlation.

\(^6\)These maps are collected from the Östhammar municipality webpage and could as such unfortunately not be incorporated with GIS. See appendix for maps.

\(^7\)Rikes koordinatsystem 1990, i.e. Swedish Grid used by National Land Survey of Sweden.
Table 1: Descriptive statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Max</th>
<th>Min</th>
<th>Std</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>1178892</td>
<td>4700000</td>
<td>260000</td>
<td>575478.3</td>
</tr>
<tr>
<td>Transaction price in SEK</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance</td>
<td>24.927</td>
<td>42.48</td>
<td>6.88</td>
<td>7.946</td>
</tr>
<tr>
<td>Distance to Forsmark in km</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Living Area</td>
<td>117.727</td>
<td>280</td>
<td>42</td>
<td>34.509</td>
</tr>
<tr>
<td>Denoted m²</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rooms</td>
<td>4.248</td>
<td>9</td>
<td>0</td>
<td>1.755</td>
</tr>
<tr>
<td>Number of rooms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lot Size</td>
<td>1503.636</td>
<td>35294</td>
<td>0</td>
<td>3583.839</td>
</tr>
<tr>
<td>Denoted m²</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>49.498</td>
<td>209</td>
<td>0</td>
<td>29.851</td>
</tr>
<tr>
<td>Age of the building in years</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age²</td>
<td>3339.531</td>
<td>43681</td>
<td>0</td>
<td>4519.151</td>
</tr>
<tr>
<td>Ocean</td>
<td>0.411</td>
<td>1</td>
<td>0</td>
<td>0.492</td>
</tr>
<tr>
<td>1 if the property is adjacent to the ocean</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of observations</td>
<td>544</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Price</td>
<td>Distance</td>
<td>Living Area</td>
<td>Rooms</td>
</tr>
<tr>
<td>------------------</td>
<td>-------</td>
<td>----------</td>
<td>-------------</td>
<td>-------</td>
</tr>
<tr>
<td>Price</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance</td>
<td>-0.032*</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Living Area</td>
<td>0.517**</td>
<td>0.025</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>Rooms</td>
<td>0.290*</td>
<td>0.0809*</td>
<td>0.547**</td>
<td>1.000</td>
</tr>
<tr>
<td>Lot Size</td>
<td>0.037*</td>
<td>0.066*</td>
<td>0.024</td>
<td>-0.032*</td>
</tr>
<tr>
<td>Age</td>
<td>-0.156**</td>
<td>0.050*</td>
<td>-0.111**</td>
<td>-0.076*</td>
</tr>
<tr>
<td>Age(^2)</td>
<td>-0.082*</td>
<td>0.043*</td>
<td>-0.054*</td>
<td>-0.039*</td>
</tr>
<tr>
<td>Ocean</td>
<td>0.215**</td>
<td>-0.501**</td>
<td>-0.008</td>
<td>-0.014</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lot Size</th>
<th>Age</th>
<th>Age(^2)</th>
<th>Ocean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lot Size</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>0.192**</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>Age(^2)</td>
<td>0.161**</td>
<td>0.921*</td>
<td>1.000</td>
</tr>
<tr>
<td>Ocean</td>
<td>-0.044*</td>
<td>-0.072*</td>
<td>-0.061*</td>
</tr>
</tbody>
</table>

*Significant at 5 %, **Significant at 1%
The line chart over number of sales over time for Östhammar municipality show no clear indication of lowered sales subsequent to the accident\(^8\).

Number of monthly sales during the period 2005-2009.

\(^8\)Other factors affecting the housing market are not taken into account and the chart should thus be interpreted with caution.
5 Results

A visual inspection of the residuals plotted against fitted values and White’s test indicated heteroskedasticity for both models and consequently Table 1 presents robust estimation results. Model 1 and Model 2 are equivalent except for the subtracted variable Ocean in the former. This is to show the importance of surrounding characteristics. A coefficient being of significance refers to a $p$-value of at least 0.1.

In model 1 Living Area, Age and $Age^2$ are all significant and of expected sign. The year dummy variables between 2007-2009 are positive and significant, the dummy for 2006 show no significantly higher prices on properties than in the year 2005. The distance coefficient is negative, implying an decrease in prices with distance, though insignificant.

The including of an ocean dummy shows some distinction from the first model. Lot Area and $Age^2$ and Age are still of the expected signs and significant. The year dummies for 2007-2009 are significant at 1 percent with positive signs. The newly added variable Ocean is positive and highly significant. The admission of an ocean dummy changes the distance coefficient from negative (-0.002) to positive (0.004) and increases the significance of the variable, an 1 unit increase in distance from Forsmark is expected to increase the price with 0.4 percent. The small positive distance estimate is however not significant, though very close to significance at a 10 percent level. The null-hypothesis of no change in prices with distance can be rejected with a risk of 10.4 percent. Controlling for properties adjacent to the ocean is thus of some importance as prices close to the plant possibly are higher due to their location in relation to the ocean i.e. their proximity to the sea. The noticeable change in the $\bar{R}^2$ term likewise confirm an improvement of admitting the variable Ocean to the model.

The low insignificant increase in distance with price might reflect balancing factors such as property consumers being unaware of the asserted risk or having faith in the Swedish nuclear industry causing the perception of risk to be lowered. Employees at Forsmark valuing the proximity to their workplace could also be contributing.

This outcome suggests a possibly larger and significant distance coefficient should more variables be applied and/or increasing the number of observation. The positive estimate results, although insignificant, are in line with some of the previous literature. Allison (1999), Boyle and Kiel (2001) and Simon and Saginor (2006) show a positive effect on property prices with distance from nuclear power plants. Carroll et al (1996), Blomquist (1974), Simons (1999) and Winstead (2010) present a negative effect on property prices in proximity to areas with other externalities.
<table>
<thead>
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<th>Model 1</th>
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<td>Distance</td>
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<td>-.005</td>
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Note: Robust standard errors, p-value in parenthesis.
6 Concluding remarks

Sweden has supplied energy from nuclear power for 40 years. During this period at least four serious accidents has taken place in the world, the history of power plants thus implies that it cannot be excluded that surrounding dwellings is being exposed to risk. It is however not obvious that the awareness of this possible hazard is embraced by the consumers of properties in such areas.

This paper estimated a nuclear power plants effects on residential property values with the purpose of analyzing the impact of asserted risk of living in proximity to such a facility. The estimates were attained by applying a hedonic house price model using a robust OLS regression. The dataset of 544 observations consisted of transaction prices for single-family houses in Östhammar municipality during the period 2005-2009. Euclidean distance was produced with the assistance of a GIS and an ocean dummy was added to the equation. The main results present no significant negative effect on prices of residential properties in vicinity to the power plant Forsmark within Östhammar municipality, though the positive distance estimates are close to a significance of 10 percent. By adding an dummy for properties located in vicinity to the ocean distance changed from negative to positive, suggesting that more observations and characteristics probably could yield a larger and significant distance coefficient.

These results would most reasonably be improved through access to maps completing the GIS technique and thus being able to add neighborhood characteristics such as railways, roads, waste sites, precise distance to water etc. This could also include topography and specific landscape characteristics. A greater set of structural attributes of the properties would also have an amending effect, though the ones used all lie in the top amongst the most often appeared in hedonic pricing studies (Sirmans et al. 2005). The throughout usage of a GIS creates the possibility of applying a spatial model that together with prevailing winds could better approximate the areas expected to be influenced, even at small dosages of radioactive emissions. Collecting data on the visibility of the plant from the dwellings in vicinity would be favorable, as visibility might put in mind the related risks. View could also be analyzed as an amenity should the property be overlooking beautiful scenery.

A possible future study would be to apply a hedonic estimation with data, preferably a spatial model, from 2010 and forward to look for a spillover effect on the Swedish housing market from the Fukushima dai-ichi accident. An option to the hedonic house

9Maps needed for a GIS and detailed structural attributes of houses could be fairly expensive material, due to this reason producing a complete spatial model was unfortunately out of reach for this study.
price models is the difference in difference approach where an equivalent municipality without a nuclear power plant is used as a control and then the differences in residential property prices are compared. Such an adjacent municipality could for instance be Norrtälje. Combining datasets of structural and neighborhood attributes with interviews of the residents is a way of receiving a direct answer to the question of risk awareness. In line with Cark and Allison (1999) further studies can be made on public knowledge by including media coverage of Forsmark in 2006. Should a decision of final storage of radioactive waste at Forsmark become effective, there most certainly would be useful to analyze possible effects on the surrounding property values.

The outcome of the estimates could, other than model misspecification, possibly reflect a number of things. Unawareness of potential hazards of the area could contribute to unaffected house prices, or a very low risk perception being held by the consumers of the properties. Faith in the Swedish nuclear industry is another plausible reasoning, or it is a representation of plant workers appreciation of living in vicinity to their job site.

The implication of these results are an unaffected housing market in the area south of Forsmark, hence no costs are created in the form of a negative externality. If such a cost should become apparent, the magnitude of its influence is still up for grades. The housing market would indeed be distorted as the values are not what they else would be but the plant in turn contributes with job opportunities and electrical supply for houses and production. Nuclear power stands for about 50 percent of Sweden’s electrical supply and a subject important to the matter is how the industry of for instance iron and paper would prevail without the presence of nuclear power plants. Although not being a longterm solution, nuclear power still needs to be weighed against its alternatives before condemning it to be a negative externality and a cost to society.

Swedish nuclear power has reached a special point since the question today of whether the nuclear power is going to continue to be part of the country’s electrical supply comes with a bit of an edge. All Swedish nuclear power plants must retire within fifteen years to not adventure the safety. Creating a new power plant, decision making included, takes at least ten years before it can produce electricity. The new nuclear power law with unlimited responsibility for the power companies choosing to build new power plants might aggravate this process, hence putting off the decision of Sweden’s main future power supply. It is a sensitive debate, not only due to the risks but also because so far there is no option to fully replace the capabilities of a nuclear power plant.
References


Appendix

Maps of Östhammar municipality. Formark is located by the seafront close to the north border of the municipality.